

PHYSICAL EXAMINATION AND DETERMINATION OF BASAL METABOLIC RATES OF A GROUP OF YOUNG ADULTS (MEDICAL STUDENTS AND NURSES)

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AT the suggestion of the Medical Research Committee of the University, and with the permission of the Faculty Council of Medicine, we have carried out detailed physical examinations of 193 male and thirteen female students of the first four years of medicine, and basal metabolic rate determinations of 202 of these students. In addition we have been able, through the courtesy of Dr. G. F. Stephens, superintendent of the Winnipeg General Hospital, to carry out basal metabolism determinations of eighty-one nurses, and to utilize the (somewhat less rigorous) physical examination carried out by one of us (D. F. M.) on these nurses.

From these studies we have derived information of some value in two directions:

1. The degree of abnormality of a group of young adult males, unselected except as regards mental ability and predilection towards a medical career. (The nurses undergo a physical examination before being accepted for training, and are, therefore, to be considered a practically normal group).

2. Basal metabolic rate values of a group of normal young adults, available for comparison with the accepted tables. (This comparison is a continuation of the work of one of us¹ previously carried out with children).

The following routine of examination was used in leading to these results with all males, and a similar examination was carried out with females:

History (enquiry as to race, number of years resident in their home district, water supply there, date of last successful vaccination, previous illnesses if any, and family history); height and weight; pulse; *blood pressure* in a sitting position, at once and after fifteen minutes' rest in the same position (the reading being determined by auscultation over the lower end of the brachial artery, using a mercury column sphygmomanometer); eyes (only for pupil reflex); teeth, tonsils, and cervical glands; *thyroid* (following Hamilton and McRae's classification for size², and further noting consistency, presence or absence of nodules, thrills and bruits); *lungs* (the usual inspection, with palpation, percussion, and auscultation

both before and after cough, while in any doubtful case a stereoscopic radiogram of the chest was made); heart; abdomen; knee-jerks; skin; inguinal rings; *urine* (at least a twelve hours' specimen was examined); *basal metabolic rate* (the procedure adopted has been outlined by one of us).

Analysis of results.—One hundred and thirteen male and ten female students, and fifty-three nurses showed no evidence of organic disease, though of the males twenty-one showed some non-organic abnormality.

Ten males showed a somewhat "high" basal metabolic rate, though there was no evidence of thyroid enlargement. The high values we attribute to imminence of examinations or some other extraneous cause, and, at most, this group can only be considered hyperexcitable.

Forty male and three female students and twenty-eight nurses showed thyroid enlargement, slight except for seven males and three females (moderate), and one female (marked). Only one of this group was possibly hyperthyroid (having a basal metabolic rate definitely above normal, and tachycardia persisting after fifteen minutes, with a pulse of 100).

Thirty-one male students showed other organic abnormalities; seventeen of these showed, in addition, slight thyroid enlargement but normal basal rate. Of these abnormalities the most interesting were nine potentially hypertensive cases, four duodenal ulcers (two previously unrecognized), only two cases of pulmonary tuberculosis (apparently quiescent), only three abnormal urine findings (one previously recognized as a chronic nephritis, the other two apparently orthostatic albuminurias), and a peculiar condition in one student in which were associated a high basal metabolic rate and a persistent high red cell count (seven millions).

Note on vaccination against smallpox.—Data were obtained of 195 students, as follows: never vaccinated ten; vaccinated, but not successfully, fifteen; vaccinated suc-

cessfully but not in the past seven years 115; vaccinated successfully within the past seven years 55.

Note on blood-pressure results.—Including those with slight thyroid enlargement, 129 male students between eighteen and twenty-six years inclusive, analyzed according to age, showed an average for each year very constant throughout this age group, the systolic extremes of the yearly averages being 107 and 119, and the diastolic, 71 and 78, and there being no progressive change with age.

Basal metabolism results.—Students were examined by the same Sanborn "Handy" apparatus as was used in the measurements of children that have already been reported¹. A Sanborn-Benedict apparatus was used for nurses.

While it is not to be expected that such instruments will give the same degree of accuracy as larger experimental apparatus, yet since such smaller clinical instruments are, and will be used generally (though it would appear likely that Rabinowitch's instrument³, equally small, will give better clinical service) it seemed desirable to determine the basal values with such instruments of a large number of young adults, and to ascertain how these values compared with those calculated from height and weight measurements by the standard methods of DuBois and of Harris and Benedict.

This seemed the more desirable since the values found for children showed a marked discrepancy from Talbot's predicted values based on weight. It may be remarked here that since Cameron's values have been used in the Winnipeg General Hospital two hundred and seven children have been examined to whom these values were applied, of whom only seventeen showed definitely high values, and thirteen doubtful values, while had Talbot's predicted values been used ninety-five would have shown definitely high, and twenty-seven doubtful values. Eighty-two of these children were examined clinically by one of us (H. D. K.), and only in six cases were the basal rates higher than those expected from clinical examination. (These eighty-two showed, according to Cameron's values, sixty-eight normal, six doubtfully, and eight definitely high; according to Talbot's tables, thirty-five normal, eight doubtfully high, and thirty-nine definitely high).

It had previously been determined that the "Handy" apparatus registered 2 per cent too high values; the necessary correction was applied. The "Sanborn-Benedict" registered correct values.

Repetition of the tests with children could not conveniently be carried out except in a very few instances (though, of course, in all cases a preliminary test was given). Such repetitions seemed desirable, however, in order to test the machine, and a number were made with students, with the "Handy" apparatus. (Again, in all cases, a preliminary, unrecorded, test was made). Boothby and Sandiford's charts (based on the DuBois formulæ) were used in these tests. Harris

and Benedict's formula gives very similar figures. The results follow:

Normal students.—(1) Oct. 20, - 2 per cent; Nov. 4, +4 per cent; Nov. 13, +3 per cent.

(2) Oct. 23, +15 per cent; Nov. 6, +3 per cent; Nov. 11, - 2 per cent.

(3) Oct. 23, +6 per cent; Nov. 6, +6 per cent; Dec. 9, +3 per cent.

(4) Oct. 20, +13 per cent; Nov. 20, +14 per cent; Nov. 27, +5 per cent.

(5) Nov. 2, - 8 per cent; Dec. 3, +5 per cent.

(6) Nov. 10, - 1 per cent; Dec. 3, - 1 per cent.

(7) Dec. 8, +12 per cent; Dec. 15, +2 per cent.

Slight thyroid enlargement.—(8) Oct. 24, +1 per cent; Nov. 20, - 5 per cent; Nov. 26, - 3 per cent.

Moderate thyroid enlargement.—(9) Oct. 29, +1 per cent; Nov. 13, - 3 per cent; Nov. 26, +1 per cent.

Potential hypertension.—(10) Oct. 22, +1 per cent; Nov. 18, +1 per cent; Nov. 27, +5 per cent.

Systolic murmur.—(11) Dec. 1, +20 per cent; Dec. 16, +20 per cent.

These figures show reasonable agreement. Wherever possible, subsequently, tests which gave high results were repeated. Two normal individuals and three with slight thyroid enlargement showed at first tests rates slightly above normal, and on repetition normal figures. Six others showed a maintained high rate.

A number of comparison tests were carried out with the two machines used, with normal individuals, and with patients (in the Winnipeg General Hospital) of different metabolic grading. The comparisons are, of course, liable to some error, since, especially with patients, the strain of two consecutive tests is liable to increase the reading. All individuals agreed that the "Handy" machine was less comfortable. The results show moderate agreement:

Normal individuals (different dates).—(1) "Handy," - 15 per cent; "Sanborn-Benedict," - 13 per cent; (2) "Handy," - 4 per cent; "Sanborn-Benedict," + 5 per cent.

Non-normal individuals (consecutive tests).—(a) "Handy" machine used first, and figures given in that order: (3) - 28 per cent; - 14 per cent. (4) - 1 per cent; +14 per cent. (5) +5 per cent; +7 per cent. (6) +13 per cent; +28 per cent. (7) +35 per cent; +43 per cent.

(b) "Sanborn-Benedict" machine used first, and figures given in that order: (8) - 15 per cent; - 26 per cent. (9) 0 per cent; - 9 per cent. (10) 0 per cent; - 4 per cent. (11) +2 per cent; - 9 per cent. (12) +6 per cent; +6 per cent. (13) +10 per cent; +2 per cent. (14) +11 per cent; +22 per cent. (15) +47 per cent; +36 per cent. (16) +51 per cent; +24 per cent. (17) +57 per cent; +49 per cent.

The basal metabolic rates were measured of 123 males and fifty-seven females, classed clinically as normal. From their heights, weights, and ages the normal figures were calculated by (i) Boothby and Sandiford's chart (DuBois⁴, page 143) combined with the Sage normal standards (DuBois, page 156), (ii) Harris and Benedict's prediction formulæ (DuBois, page 161), and in addition, since presumably users of Sanborn's machines generally use the tables furnished by this instrument manufacturer, (iii) the tables supplied

by Sanborn some years ago (referred to as "Sanborn's old tables"), and (iv) those he now supplies (referred to as "Sanborn's new tables").

Of these 180 individuals, thirteen males showed at first examination obviously abnormal rates. On repetition of those available only two came within normal limits. These thirteen were excluded, in considering normal standards. The remainder are summarized in Table I.

Remembering that these results are based on an initial test (merely preceded by a short preliminary test to habituate the subject to the apparatus), the figures are in good agreement with theory, whether the DuBois or the Harris and Benedict standards are used. (Since the former is based on an undoubted connection between heat loss from a surface and heat supply to that surface, while the latter is purely empirical, we prefer to use the DuBois standards). The extremes observed fall closely within the limits emphasized by Benedict, plus or minus fifteen per cent, so far as males are concerned, while the figures tend to be very slightly lower for females, the average being minus 2 per cent for them, as compared with 0 per cent for males.

The figures obtained with Sanborn's old tables are in good agreement, but those with the new tables are distinctly higher—about 5 per cent throughout. The reason of this discrepancy appears to be the fact that the spread of age given in Sanborn's tables is too great (twenty to fifty years). The old tables appear to apply correctly to the age-group twenty to thirty, the new

tables to the age-group forty to fifty, and each table requires a correction for other ages. Obviously the high figures obtained with the new tables in many cases in the above results would lead to error if employed clinically.

The discrepancy between Talbot's and Cameron's figures, as far as measurements in Winnipeg are concerned, is not paralleled for young adults, and either the DuBois or Harris and Benedict standards can be used correctly for them.

Note on thyroid enlargement.—Analysis of the proportion of thyroid enlargements at different ages shows no definite regression with increasing age in either male or female subjects. Twenty-six per cent of all the males examined showed enlargement, thirty-seven per cent of all the females.

Note on calculation of basal metabolic rate from pulse pressure and rate.—Read⁵ has suggested that it is possible to calculate the basal metabolic rate from the blood pressure and pulse, using the formula

$$\text{B.M.R.} = 0.683 (\text{P.R.} + 0.9 \text{ P.P.}) - 71.5,$$

where B.M.R. indicates the basal metabolic rate, P.R. the pulse rate, and P.P. the pulse pressure. At the suggestion of Dr. W. D. Macdonald we have tested Dr. Read's formula with our results. Blood pressure and pulse rate measurements were made of eighty-eight students, in all cases after the determination of the basal metabolic rate, so that these students had been resting prone for at least three-quarters of an hour. In seventy of the eighty-eight cases normal results were obtained by both methods, and in forty of these the differences did not exceed 5 per cent. Four cases of slight hypertension showed, as is to be expected, higher values by the blood pressure formula (respectively 22, 18, 12, and 6 per cent higher), and in two of these the values obtained by this method were above normal. In nine cases in which high "basal" rates were recorded through excitement or some similar extraneous cause, the figures determined from the blood pressure and pulse were normal. The explanation would appear to be a more rapid return of blood pressure and pulse to normal following excitement, than of tissue catabolism. Had the blood pressure and pulse readings been taken before the metabolic rate, they would also probably have indi-

TABLE I
BASAL METABOLIC RATES OF NORMAL YOUNG ADULTS

Sex	Age	No.	DuBois Standards		Harris and Benedict Standards		Old Sanborn Standards		New Sanborn Standards	
			Extremes %	Mean %	Extremes %	Mean %	Extremes %	Mean %	Extremes %	Mean %
Male.....	18	5	-10—+6	+2	-9—+9	+3	-11—+6	+1	-5—+11	+6
	19	11	-6—+15	+3	-2—+17	+6	-7—+13	+2	-2—+19	+7
	20	12	-6—+15	+4	-6—+13	+4	-6—+15	+5	-1—+21	+10
	21	12	-10—+15	+1	-11—+13	0	-9—+16	+2	-5—+21	+7
	22	22	-13—+14	0	-16—+15	-1	-13—+15	+1	-9—+20	+5
	23	8	-9—+10	-3	-10—+10	-3	-9—+10	-3	-5—+16	+2
	24	19	-13—+14	0	-13—+16	-1	-13—+16	0	-9—+22	+5
	25	8	-17—+2	-6	-16—+4	-5	-16—+2	-6	-12—+7	-1
	26-32	17	-15—+13	-1	-16—+14	-0	-15—+13	-1	-11—+19	+4
	Total.....	110	-17—+15	0	-16—+17	0	-16—+16	0	-12—+22	+5
Female.....	18	5	-5—+17	+1	-8—+15	0	-7—+16	0	-3—+22	+5
	19	7	-17—+1	-8	-19—+4	-6	-19—0	-9	-15—+4	-5
	20	16	-16—+10	-3	-17—+11	-3	-16—+11	-2	-10—+17	+3
	21	8	-12—+9	0	-12—+11	-1	-9—+11	+2	-6—+17	+7
	22-24	12	-13—+12	-2	-15—+7	-2	-12—+13	-1	-9—+18	+4
	25-29	9	-7—+3	-1	-3—+4	0	-5—+4	0	-0—+9	+5
	Total.....	57	-17—+17	-2	-19—+15	-2	-19—+16	-2	-15—+22	+3

cated a high rate. Of the remaining three cases one showed a basal rate of plus 5; that calculated from the formula was minus 24 per cent. His pulse was only 50. The second showed on two occasions a basal rate of plus 43 and plus 31 per cent; the corresponding figures from the formula were minus 8 and 9. The third, possibly hyperthyroid, gave by the two methods the respective figures plus 50 and plus 24 per cent.

In addition, a number of pathological cases were measured in the Winnipeg General Hospital following a basal metabolism test.

Of ten showing a normal basal rate seven showed a normal rate from the formula; the remaining three showed a rate above normal from the formula, the differences being respectively 14, 30, and 30 per cent.

Of nineteen cases showing a high basal rate six gave a normal rate from the formula (the average figure being 15 per cent. lower), and while the other thirteen showed a high rate also, the actual figure was usually much lower (averaging 17 per cent less), though in three exceptions the formula-figure was respectively 5, 17, and 20 per cent higher.

One case showed a doubtfully low rate of minus 14 per cent, and a definitely low formula figure of minus 22 per cent.

It would, therefore, appear that whilst in most cases, and especially with normal individuals, the two methods lead to similar results, yet the exceptions are sufficiently numerous, with variations in both directions, to prohibit reliance being placed on figures calculated from the blood pressure and pulse.

It might appear useful to obtain this additional information in order to check up a basal rate determination, but it seems to us very doubtful if more information would be obtained than from the ordinary clinical examination.

There is one final point concerning which the usefulness of the formula might be considered. An initial determination might be made of the basal rate directly, and from the formula, with subsequent determinations of the latter (especially where, as in country districts, metabolic apparatus might be lacking) in order to check up changes in the former. Such a procedure involves the assumption that for one patient the two sets of figures would run parallel. We have only one set of comparisons to test this, but this series lends no support to such an assumption.

Miss K.—May 19 B.M.R.	+39%	formula-figure	+21%
May 25	+76		+30
June 3	+77		+32
June 8	+39		+20
June 15	+31		+23

Our results, therefore, do not lend support to the use of Read's formula for the clinical determination of the basal metabolic rate.

Discussion of Results

Of 193 male students examined only ninety-two (47.6 per cent) can be regarded as functionally and physically perfect, and 113 (58.5 per cent) as functionally normal. The group of female students is too small to analyze similarly, and the group of nurses does not come within a similar unselected category. Amongst the females slight thyroid enlargement is the only abnormality.

Such slight thyroid enlargement is the chief abnormality in both sexes, in agreement with the fact that the Winnipeg district comes within the goitre belt of North America.

Our technique in measuring blood pressure follows that of Adamson⁶, and our results empha-

size the point he stresses that a "basal" blood pressure can only be obtained after a period of rest, and a "basal" pressure must be measured if any accurate conclusions are to be drawn from it. The mean initial blood pressure of 129 normal male students (including those with slight thyroid enlargement and normal basal metabolic rate) between the ages of eighteen and twenty-six inclusive was 124/80, while the corresponding mean "basal" measurement was 112/73. Further, the initial readings showed much wider fluctuations. It will be noted that while the diastolic pressure showed an average fall of only 7 mm. mercury pressure, the systolic pressure showed a fall of 12 mm.

The physiological effect of respiration on the systolic blood pressure was quite marked in many cases, the point of audibility being in some instances from 8 to 10 mm. mercury pressure higher during expiration than during inspiration. The reading taken as representing the systolic blood pressure was that point where all the beats were audible in both phases of ordinary respiration.

Vincent and Cameron⁷ have discussed the marked effect of forced breathing on blood pressure, to which this seems to be the normal physiological parallel.

We know of few examinations of students reported in the literature similar to those given in this paper. The most extensive is that of Alvarez⁸, who has summarized the results of examination of 15,000 students of the University of California, carried out by different clinicians. The method employed does not appear to be comparable to ours. Blood pressure findings especially were dealt with. Adamson has criticised the technique used. No "basal" readings were obtained, and it is doubtful if Alvarez's conclusions are valid. Legge⁹ has analyzed the urine findings of 1,224 students entering the University of California. Only fifty-one showed abnormalities, the most prominent being albuminuria; this was in all but six cases of physiological origin. Lord Dawson of Penn¹⁰ has recently emphasized the occurrence of hypertension in children and young adults.

Our results suggest the desirability of a careful examination of all university students, and especially of students in a medical school, in which such examination can most reasonably be demanded and most efficiently controlled. The abnormalities found in only the small group we have examined are sufficient to justify such an

examination from the point of view of prevention and early treatment. We note that Baylor University College of Medicine¹¹ is now demanding such examination of all entrants, and is further demanding vaccination against smallpox, and urging vaccination against typhoid and paratyphoid fevers.

Summary

The results are detailed of a physical examination of a moderately large group of young adults. The most frequently occurring abnormality was slight thyroid enlargement.

Adamson's contention that blood pressure readings should be made under "basal" conditions, if definite conclusions are to be drawn, receives support.

The basal metabolism figures of 110 normal males and fifty-seven normal females of ages varying from eighteen to thirty-two years are in agreement with the DuBois and Benedict standards.

The "Sanborn" tables at present in use are about 5 per cent too high for adults of these ages and may lead to error if employed clinically.

Read's formula for calculation of the basal

metabolic rate from pulse pressure and pulse rate has been tested with a group of normal and pathological individuals and the results do not justify the use of this formula clinically.

We desire to thank Dr. Margaret Rioch for carrying out the physical examination of the women students under our direction, and those members of the Faculty who have co-operated by carrying out special examinations, especially Dr. D. A. Stewart and Dr. J. C. McMillan, and, further, Dr. G. F. Stephens for facilities in the Winnipeg General Hospital during the clinical examinations. Our thanks are also due to Misses J. E. Williamson, C. Gibson, and M. Ferguson for assistance in carrying out the basal metabolism measurements.

REFERENCES

- (1) CAMERON, *Can. Med. Assoc. J.*, 1925, xv, 1,022.
- (2) HAMILTON AND McRAE, *Can. Med. Assoc. J.*, 1925, xv, 1,017.
- (3) RABINOWITCH AND BAZIN, *Can. Med. Assoc. J.*, 1926, xvi, 638.
- (4) DuBOIS, "Basal metabolism in health and disease," Philadelphia and New York, 1924.
- (5) READ, *J. Am. Med. Assoc.*, 1922, lxxviii, 1,887.
- (6) ADAMSON, *Can. Med. Assoc. J.*, 1925, xv, 1,112.
- (7) VINCENT AND CAMERON, *Quart. J. Exp. Physiol.*, 1915, ix, 64.
- (8) ALVAREZ, *Arch. Int. Med.*, 1923, xxxii, 171.
- (9) LEGGE, *J. Am. Med. Assoc.*, 1925, lxxxiv, 1,030.
- (10) LORD DAWSON OF PENN, *Proc. Roy Soc., Med.* 1926, xix, 27.
- (11) ANON, *Bull. Assoc. Am. Med. Coll.*, 1926, i, 3c.

The Pathogenesis of Hypertension—a New Theory.—The immediate causes of arterial hypertension are still sufficiently uncertain to warrant a lively interest in any engaging new hypothesis. Studies on the pathogenesis of hypertension, carried out by Bordley and Baker in the department of pathology of Johns Hopkins Hospital, have been stimulated by the demonstration of Anrep and Starling of London that a reduction in the amount of blood reaching the part of the brain concerned with vasomotor control brings about a compensatory rise in the systemic arterial pressure. This was effected by the ingenious experiment of making the circulation through the brachiocephalic artery of an experimental animal independent of the rest of the blood supply of the body. The circulation through the medullary vascular centers could thus be controlled and made independent of changes in the heart or in the splanchnic vessels. A fall in the blood pressure in the brain pro-

duced immediate vasoconstriction in the rest of the animal. Bordley and Baker have found arteriosclerosis in the medulla oblongata without exception in man in cases with a history of hypertension, whereas the arterioles in this region were found unaltered when there was a record of normal blood pressure. The Baltimore pathologists, recognizing the current belief that arterial hypertension is accompanied by arteriosclerosis in at least some portion of the body, suggest that a localization of this process in the medulla oblongata may be the essential factor in the production of persistent high blood pressure. The possibility remains, of course, that the anatomic changes may be secondary to the hypertension. Bordley and Baker tentatively conclude that there is at least an association between persistent hypertension and arteriosclerosis of the vessels supplying the brain stem.—*Journal American Medical Association*, July 24, 1926.